Determination of Indicators of Ecological Change

SEMP Project CS-1114A-99
Ft. Benning, GA

University of Florida
and
Purdue University

Wetlands Biogeochemistry Laboratory

3. 9. 2001

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Research Team

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- **Jennifer Jacobs,** University of Florida, Surface hydrology
- **James Jawitz,** University of Florida, Subsurface hydrology
- **Debbie Miller,** University of Florida, Vegetation ecology, habitat integrity, biodiversity
- **Andy Ogram,** University of Florida, Soil microbiology
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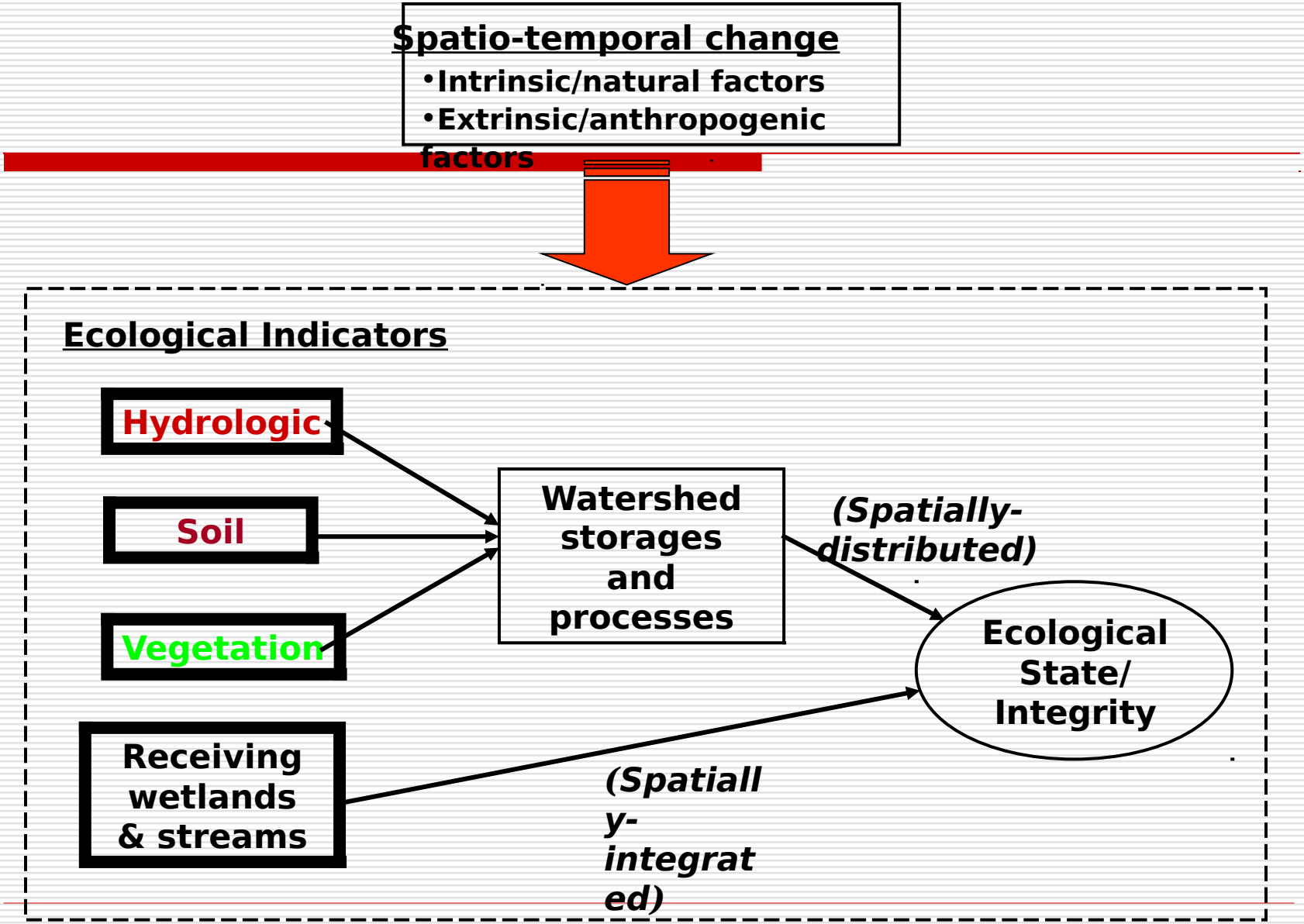
- **Suresh Rao,** Purdue University, Subsurface hydrology, modeling
- **Ramesh Reddy,** University of Florida, Soil biogeochemistry
- **George Tanner,** University of Florida, Vegetation ecology, habitat integrity
- **Several graduate students and post docs.**

Technical Objectives

- **Identify physical, chemical and biological variables (properties and processes) associated with soil, surface/subsurface hydrology and vegetation that may be used as indicators of ecological change**
- **Evaluate potential ecological indicators based on sensitivity, selectivity, ease of measurement and cost effectiveness**

Technical Objectives

- **Select Indicators that most effectively:**
  - **Show a high correlation with a certain state in a specific ecosystem**
  - **Provide early warning of impending change**
  - **Differentiate between natural ecological variation and anthropogenic impacts**
- **Determine the likely range of natural variation for indicator variables, and compare with the range of values under anthropogenic, especially mission-related influences**


Spatio-temporal change
•Intrinsic/natural factors
•Extrinsic/anthropogenic factors
Ecological Indicators
Hydrologic
Soil
Vegetation
Receiving wetlands & streams
Watershed storages and processes
(Spatially-distributed)
Ecological State/ Integrity
(Spatially-integrated)

Thrust Areas

- Soil Biogeochemistry
  - Spatial study
  - Disturbance and Landuse gradients
  - Mechanisms
  - Integrative (CCA analysis, hyperspectral)
- Vegetation
  - Spatial study
  - Chronosequence (Recovery from disturbance)
- Watershed Hydrology
  - Soil water storage
  - Watershed hydrology and nutrient dynamics

Outline

- TAC Review Comments
- Work to date
  - Biogeochemistry
    - Data Analysis / Synthesis
    - Hyperspectral Analysis
  - Vegetation
  - Hydrology
  - Integration efforts
- Ongoing projects
  - Litter decomposition and carbon cycling
  - Vegetation species indicators
  - Riparian Ecosystem Management Model

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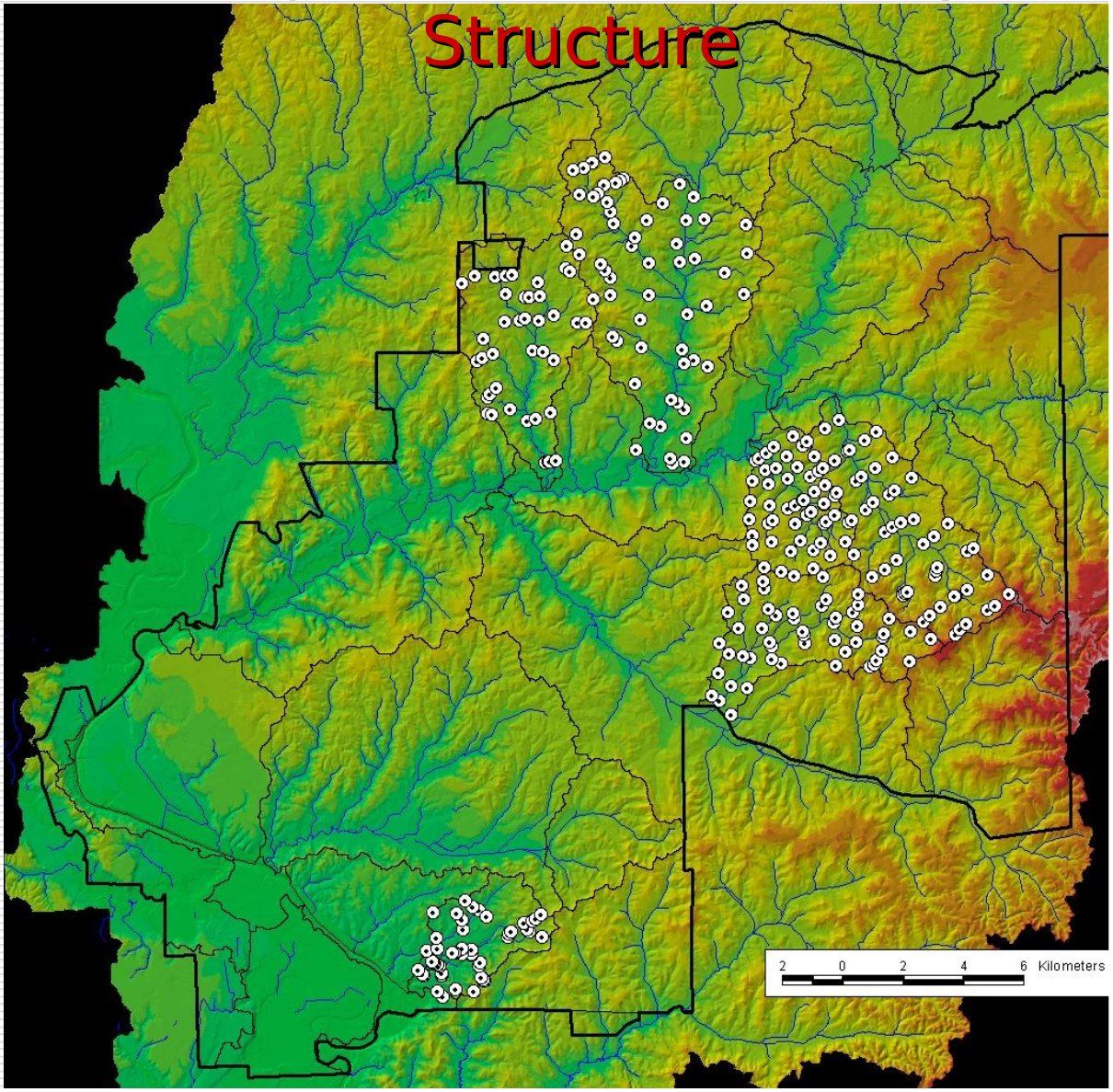
Research Report
FY 2002-03

TAC Recommendations

- **Continue the efforts to integrate the various components of the projects**
- **Vegetation component.. specific role in the project**
- **Emphasize the preparation of refereed publications.. Significant progress by next TAC meeting**
- **Integration of all components of the project**

Soil Biogeochemistry and Vegetation Community Structure



Spatial Study

300+ soil sites

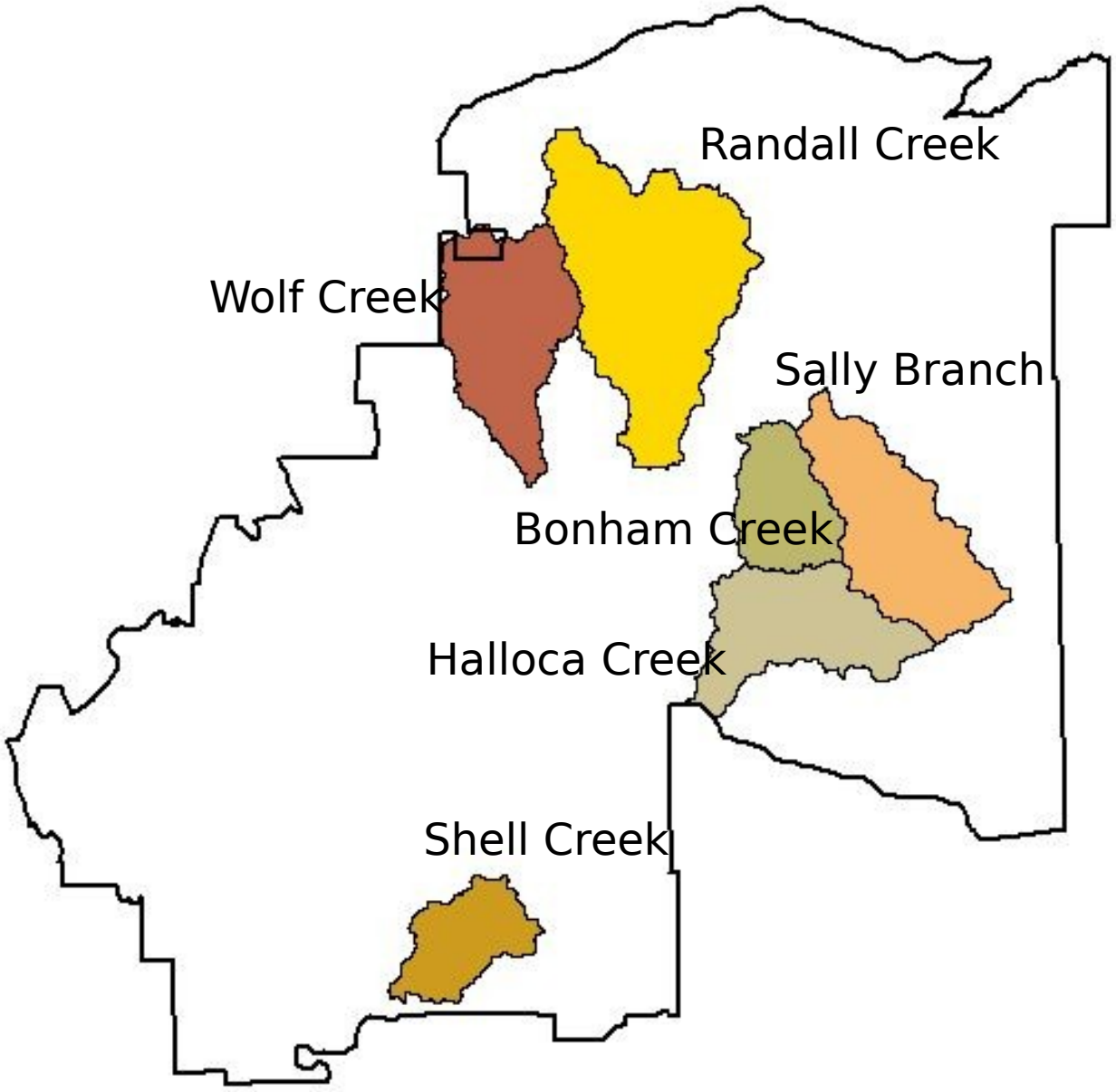
(n=56 microbial)

Stratified into:

- Upland
- Mid-slope
- Bottomland

Field observations at every site:

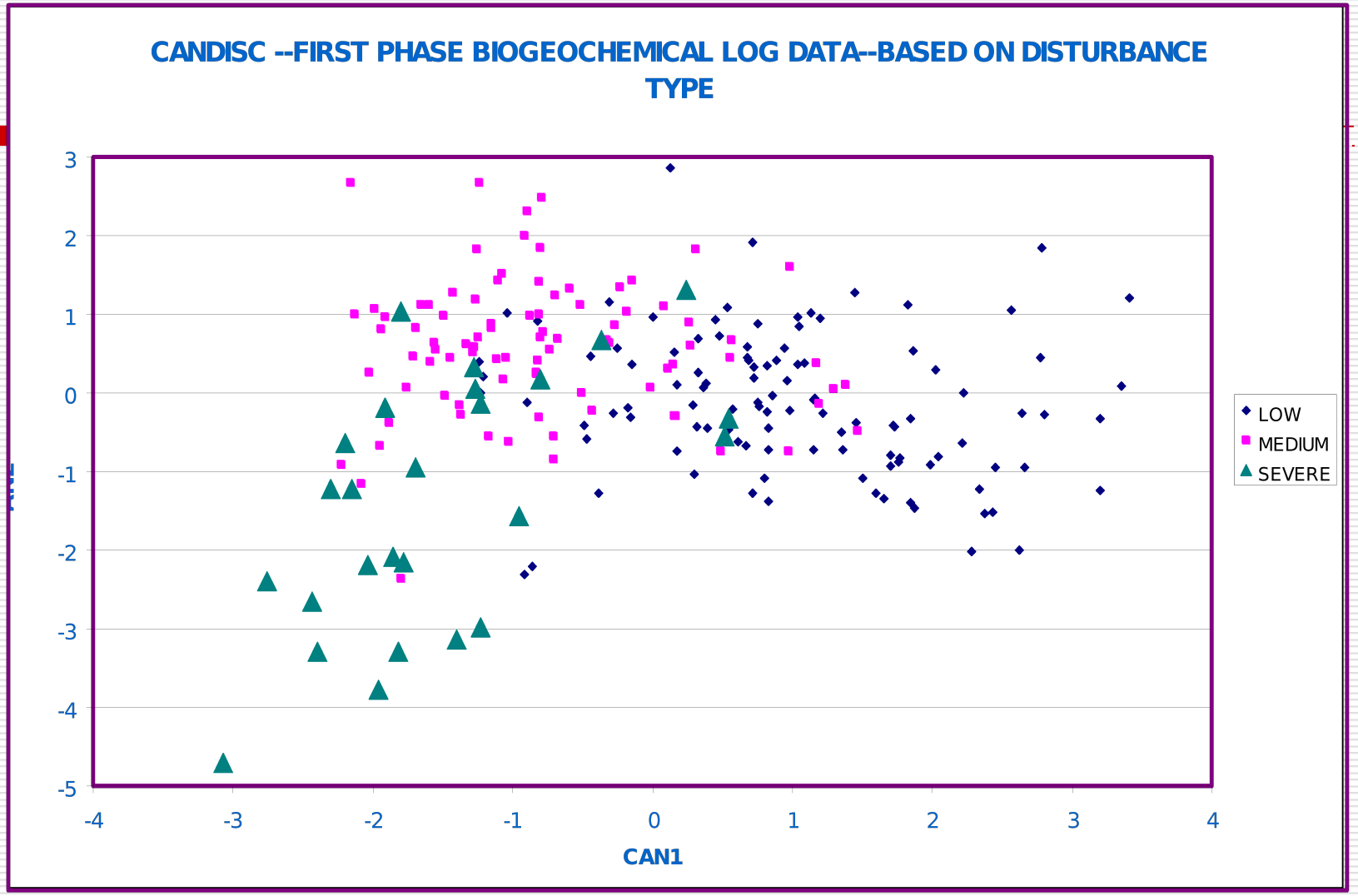
- % cover of canopy, understory, ground
- Disturbance level
- Type of disturbance



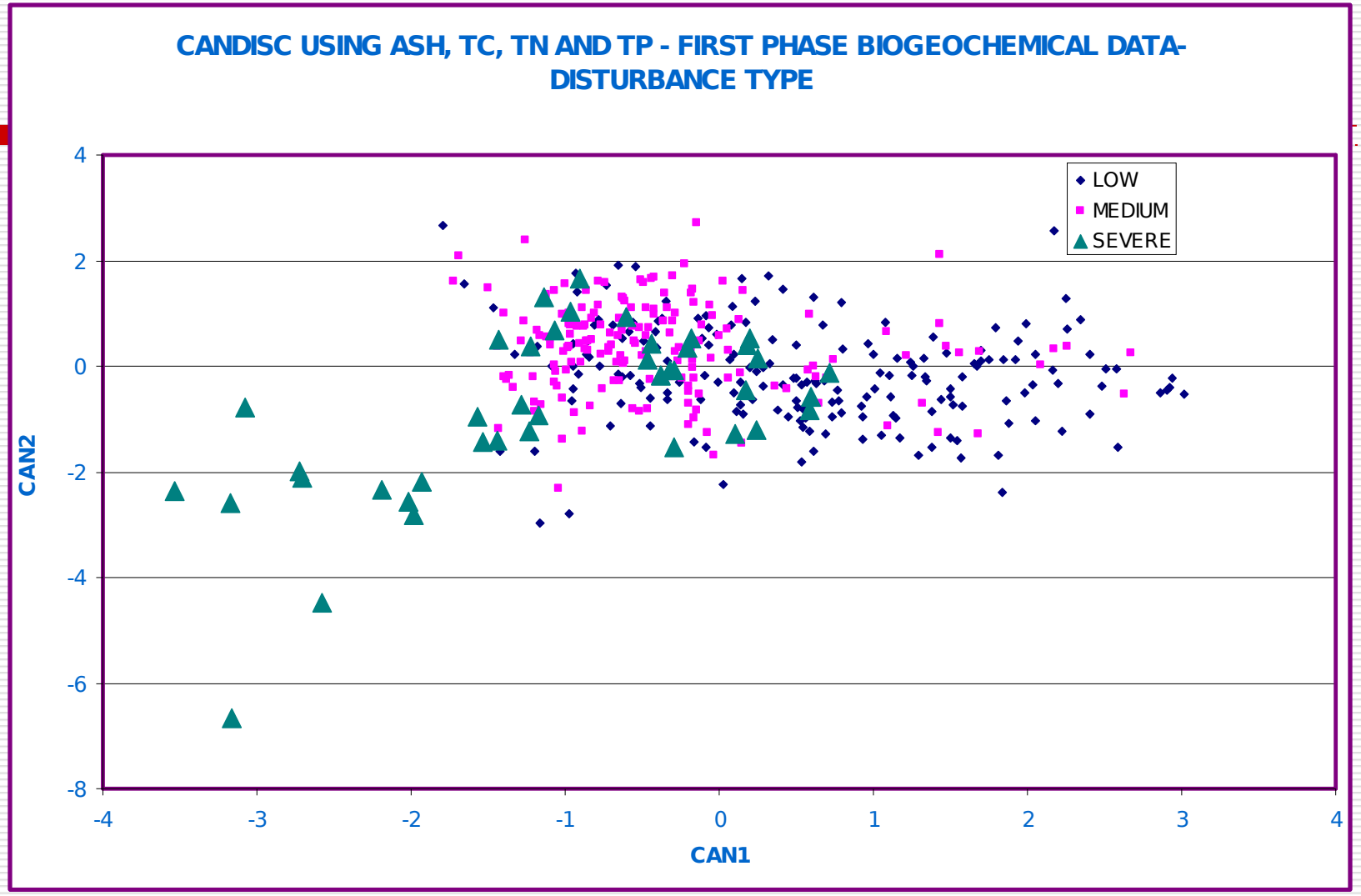
Soil Parameters (Phase 1):

pH
Total C **Water Extractable C** **Microbial C** **Soil respiration (CO_2 prod.)**
Total N **Exchangeable NH_4^+** **Microbial N** **PMN** **Arginine ammonification**
Total P **Water Extractable P** **HCl Extractable P** **Oxalate Extractable P** **Mehlich-1 P** **Microbial P**
Mehlich-Fe, Al, Ca, Mg, K **Oxalate-Fe, Al**
Acid Phosphatase **Beta-Glucosidase** **Dehydrogenase** **Protease** **Microbial diversity**

Canonical Discriminant Analysis



Canonical Discriminant Analysis



SOIL PROPERTIES ALONG DISTURBANCE AND LAND USE GRADIENTS

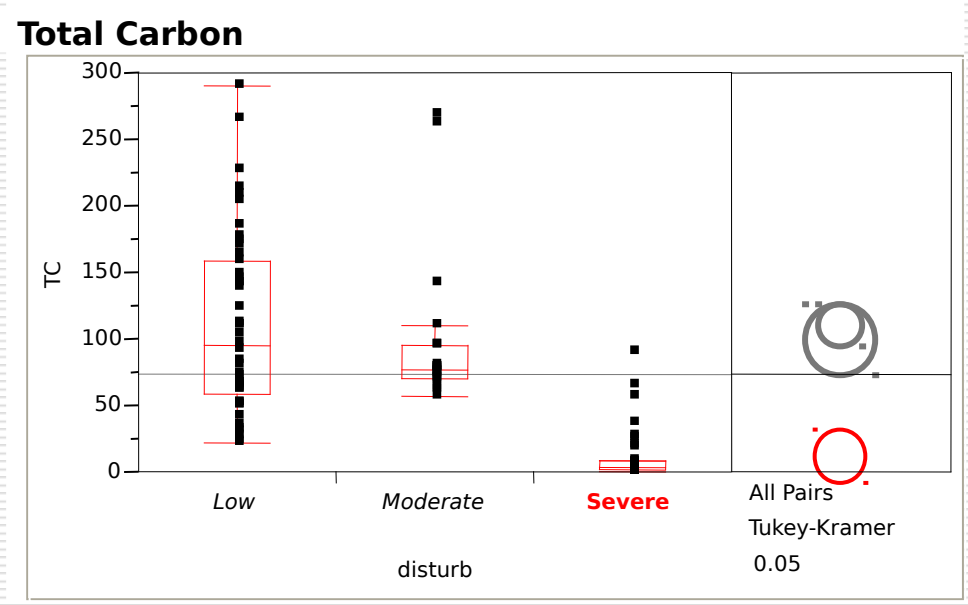
High-disturbance site – Military impact gradient

Low-disturbance site – Land use/management

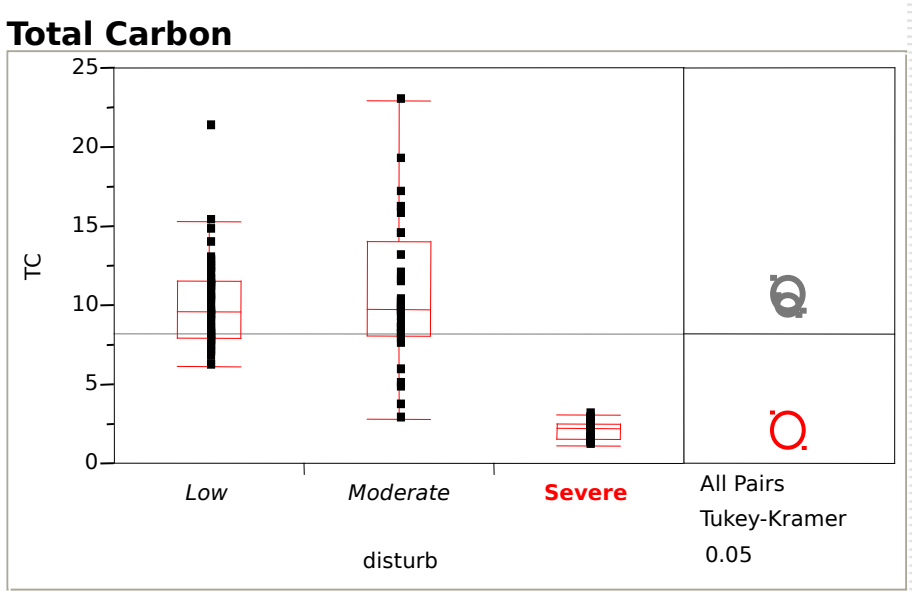
TOTAL ORGANIC CARBON

transects

Wetlands

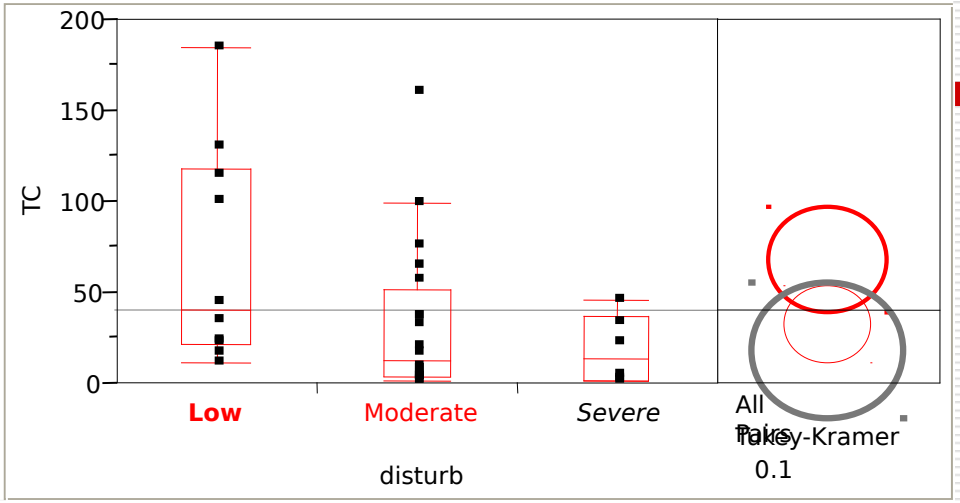


Uplands

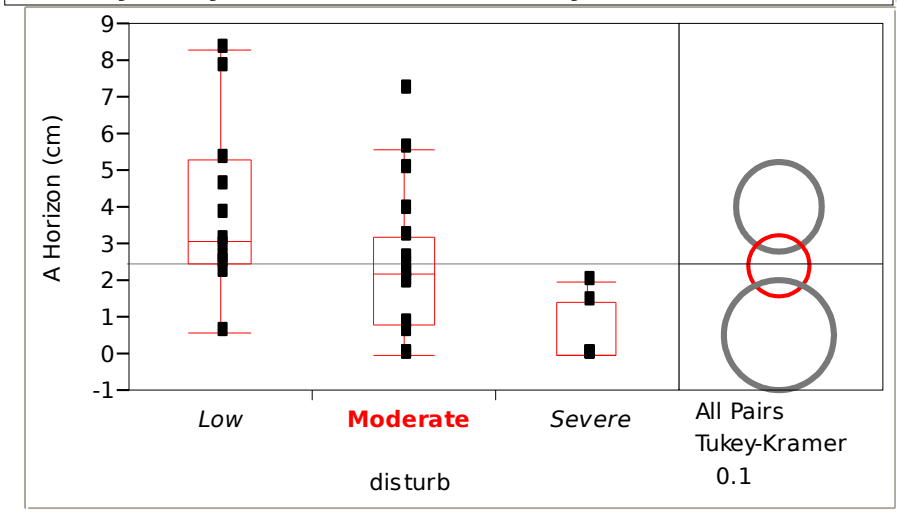


Potential Indicators

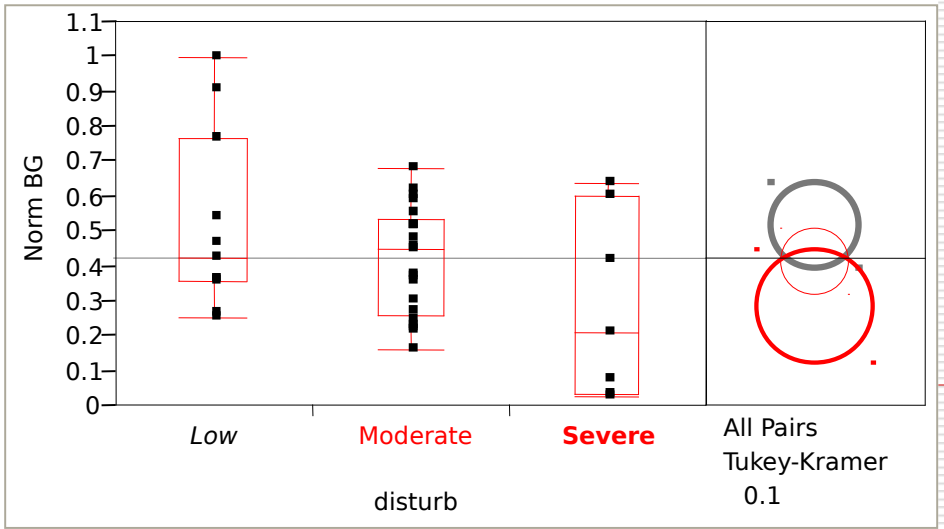
Total Carbon



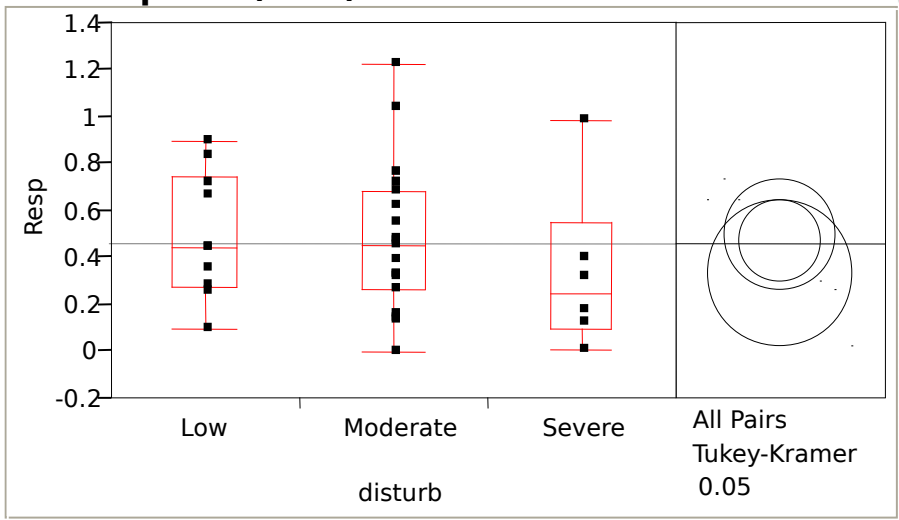
Oneway Analysis of A Horizon (cm) By disturb



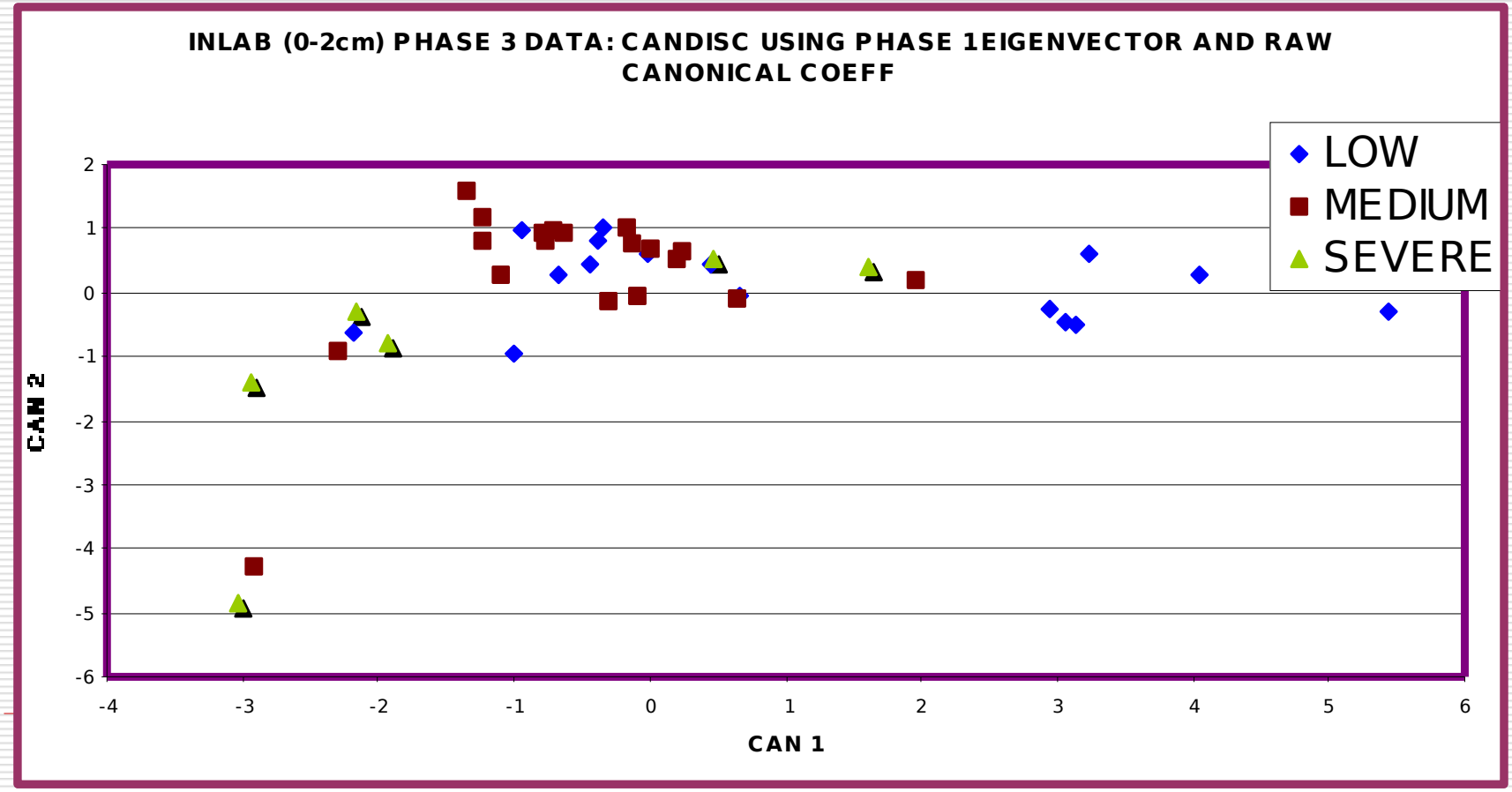
Normalized Beta Glucosidase



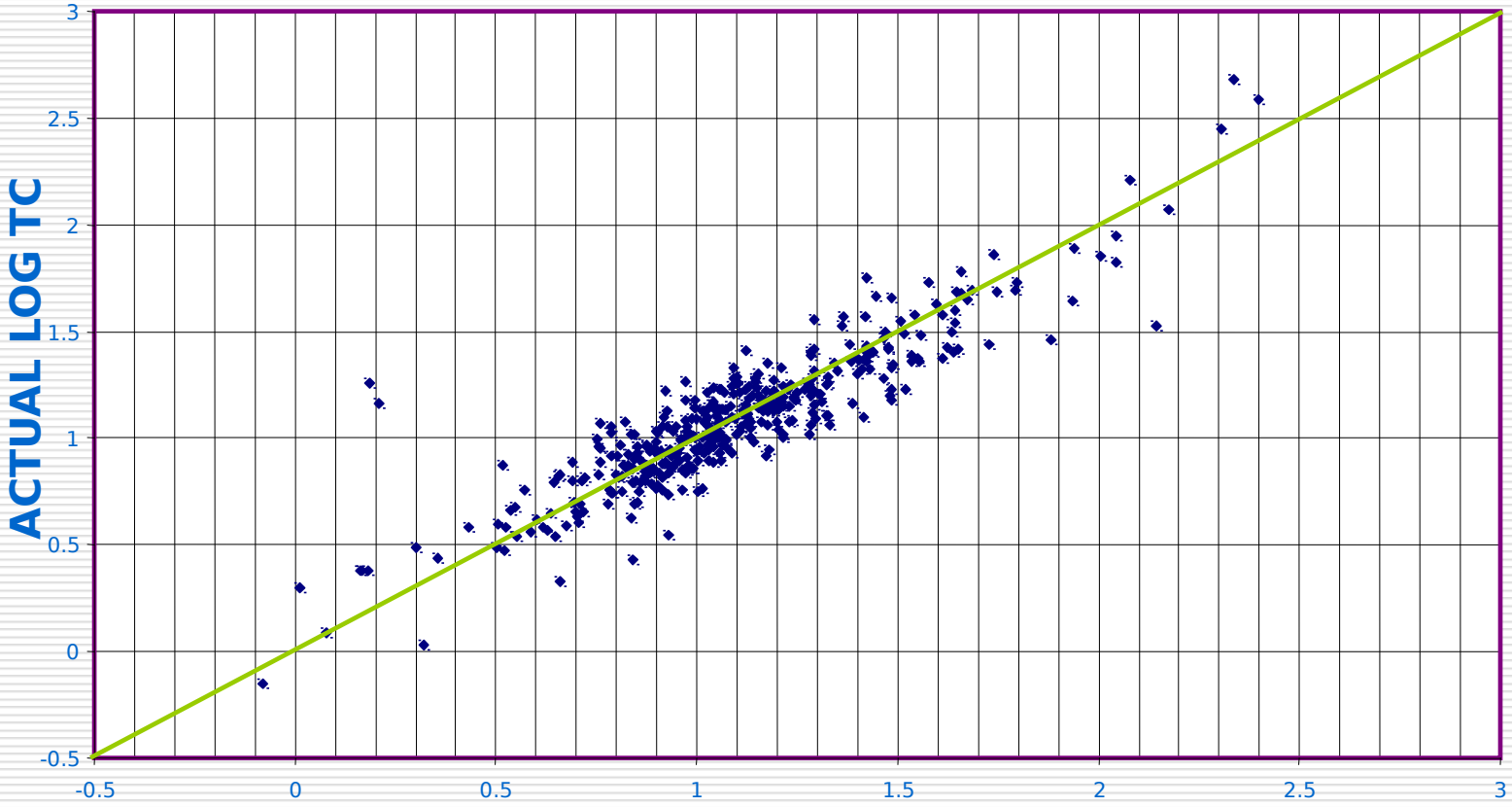
Soil Respiration (field)



Hyperspectral Reflectance: Validation of Phase 1 models with the top 2 cm (in-lab).



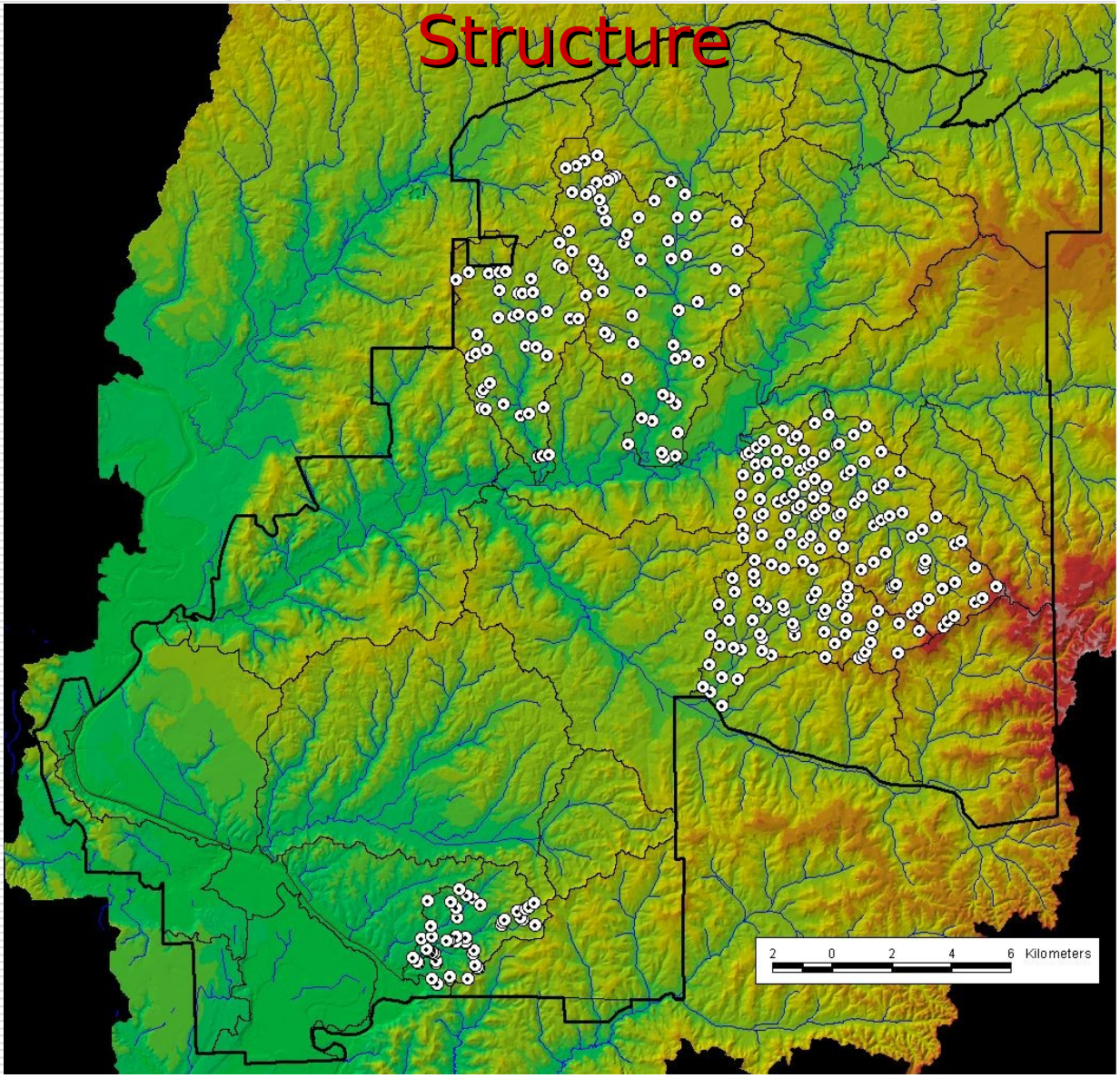
PLS PREDICTED LOG TC FOR THE FIRST PHASE SITES USING ONE CROSS VALIDATION



Biogeochemistry Summary

- Primary impacts are loss of O and A horizons in uplands
- Concomitant sedimentation in bottomlands (dilution of organic matter).
- Canonical Discriminant Analysis
  - Ash, TC, TN, TP
- Hyperspectral Analysis
  - Separates as well as chemical analysis
  - Rapid

Soil Biogeochemistry and Vegetation Community Structure



Spatial Study

273 vegetation sites (n=56 biomass)

Stratified into:

- Upland
- Mid-slope
- Bottomland

Structure & Composition of Vegetation:

- Woody canopy
- Overstory canopy (densiometer)
- Herbaceous cover, density, and biomass
- biomass

PHASE 1 Analysis
Woody Species – 113 species

Canonical Correspondence Analysis (CCA)

- Distribution and cover of woody understory species more strongly related to soil texture and secondarily to level of military disturbance
- Differentiation of species associated with low disturbance greater than that for moderate and severe sites
- Severe disturbance sites are closely associated with upland, sandy clay (Sc) soils

PHASE 1 Analysis
110 Herbaceous Species

Canonical Correspondence Analysis (CCA)

- Uplands - herbaceous vegetation influenced more by disturbance than by soil variation
- Severe disturbance sites clearly separated from low and moderate levels but little differentiation between low and moderate
- Indicator analysis – % bareground only significant indicator of severe disturbance

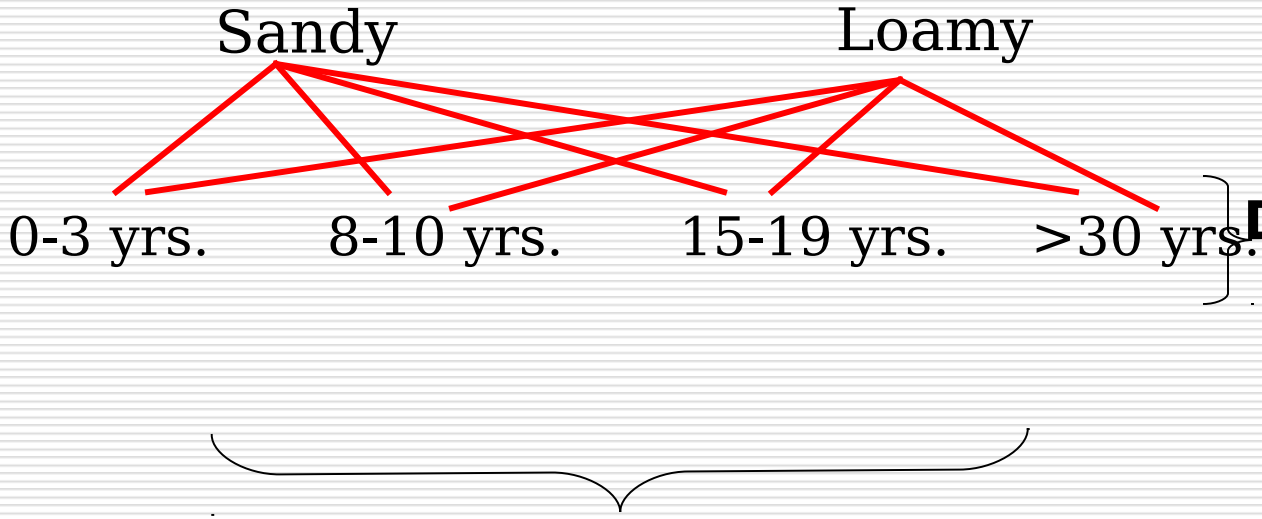
Vegetation and soil response to timber operations: A chronosequence study

Phase II : Chronosequence Study Objectives

Logging activity without military activity

- Determine understory vegetation response to soil variables and age since clear cut
- Determine if individual herbaceous or understory woody species may be used as indicators of time since clear cut

Site Selection

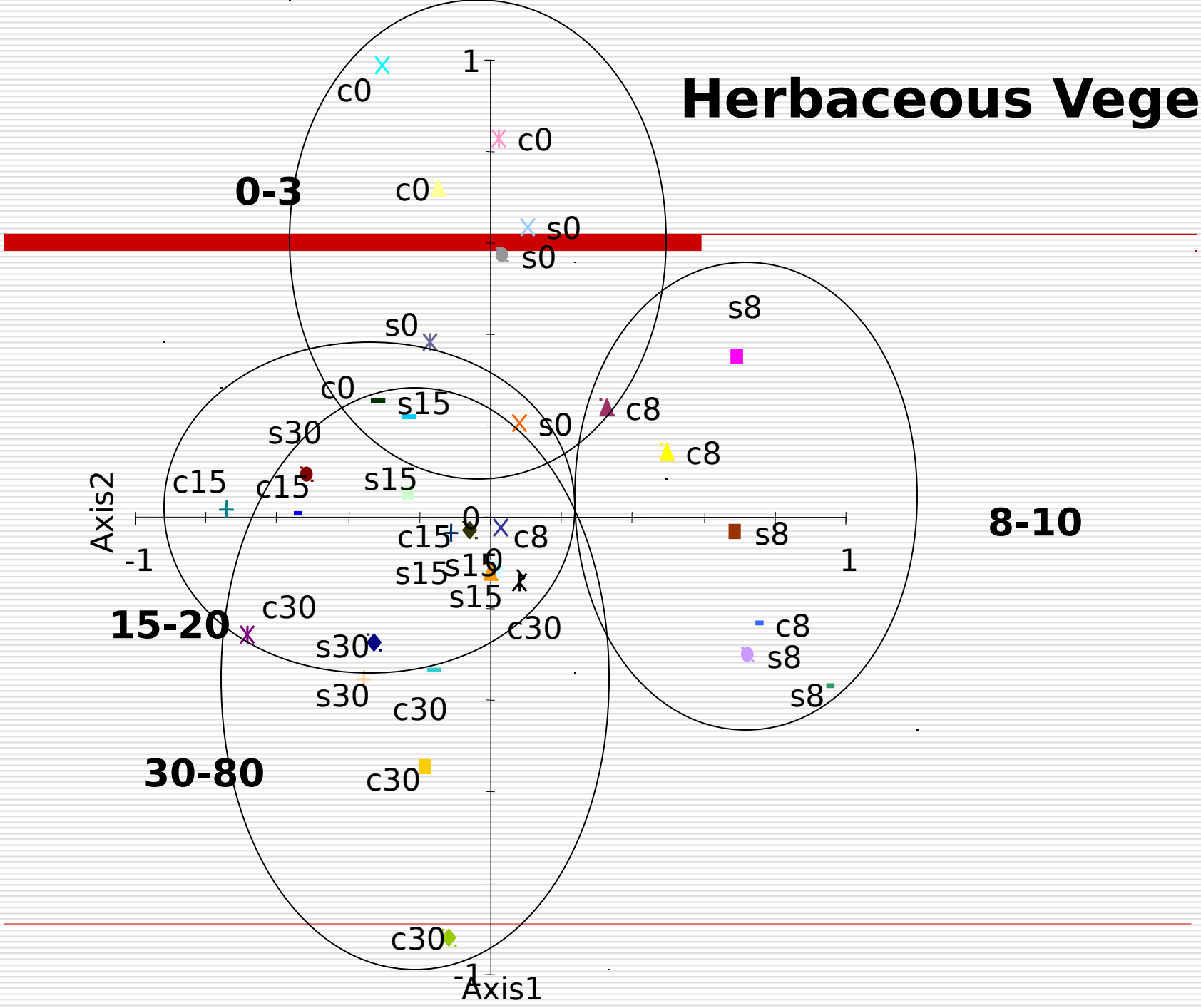


32 Sites: 4 sites in each age group in each soil type
(confounding variables kept constant)
fire, position, herbicide, slope

PHASE 2 Analysis
158 Herbaceous Species

Canonical Correspondence Analysis (CCA)

- Soil Variables: low ranges in upland sites
  - –not well correlated with level of disturbance
  - –not well correlated vegetation distribution
  - –BD only correlated with disturbance and vegetation
- Age Class most important variable effecting vegetation distribution and abundance
  - –Most change occurs in first 3 age classes
- Herbaceous vegetation more effected by and better indicator of disturbance that woody understory vegetation


Herbaceous Vegetat
0-3
8-10
15-20
30-80
Axis2
Axis1
-1
0
1
c0
s0
s8
c8
s15
c15
s30
c30

Indicator Analysis

- > 30 age class (AC) - 6 significant herbaceous and 1 woody indicator species identified
- 15-20 AC – 3 significant herbaceous indicator species
- 8-10 AC – 3 significant herbaceous indicators
- 0-3 AC – 1 significant herbaceous indicator

Watershed Hydrology

- Characterize hydraulic properties from undisturbed soil-cores taken from field sites
- Explore relationship between soil-water retention parameters, hydraulic conductivity, and soil-water storage estimates
- Investigate spatial and temporal patterns of soil-water storage in Bonham-1 sub-watershed
- Investigate watershed flow processes from spatial information dealing with: saturated hydraulic conductivity, stream hydrographs, hyetographs, and soil-water storage

Soil Bulk Density & Porosity in Impacted & Un-impacted Areas

Bulk Density in Impacted areas	
Mean	1.588
Median	1.578
Standard Deviation	0.158
Standard Error	0.0264
Skewness	0.545
Range	0.617
Count	36

Bulk Density in Unimpacted areas	
Mean	1.377
Median	1.396
Standard Deviation	0.130
Standard Error	0.0171
Skewness	-0.392
Range	0.645
Count	58

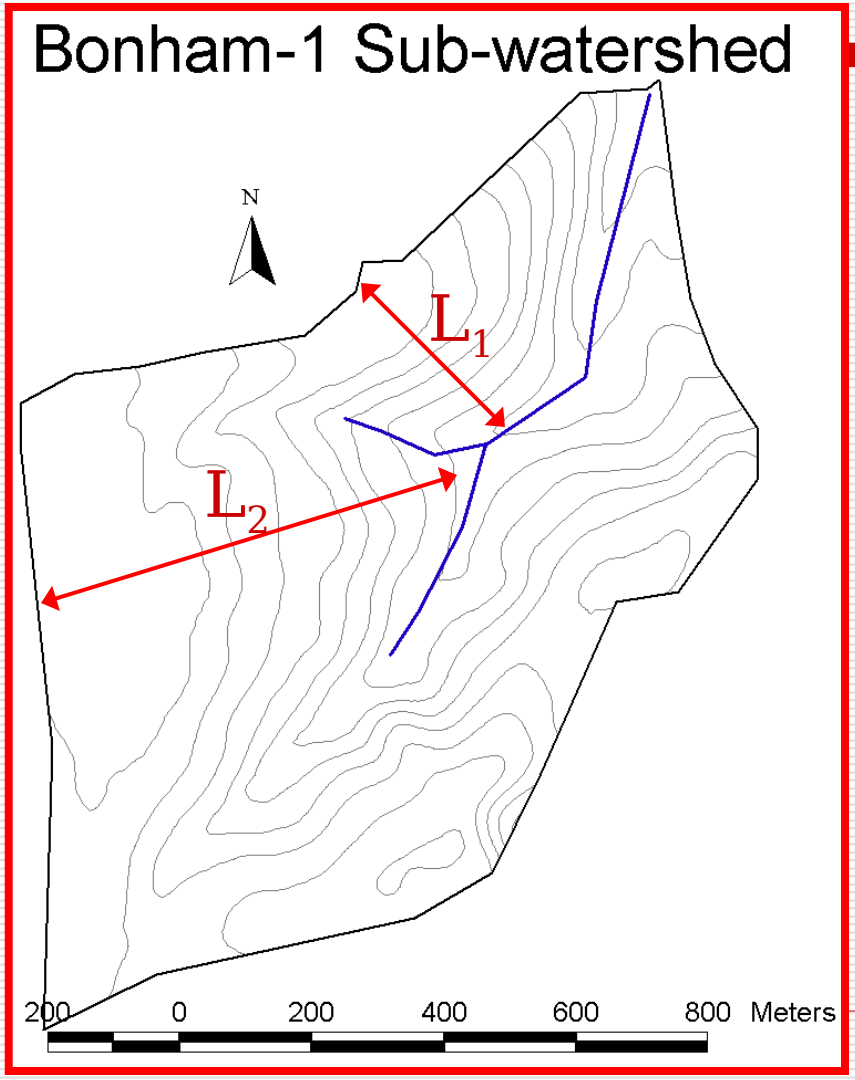
Porosity in Impacted Areas	
Mean	0.401
Median	0.405
Standard Deviation	0.060
Standard Error	0.010
Skewness	-0.545
Range	0.233
Count	36

Porosity in Unimpacted Areas	
Mean	0.480
Median	0.473
Standard Deviation	0.049
Standard Error	0.006
Skewness	0.392
Range	0.244
Count	58

Soil Bulk Density & Porosity in Impacted & Un-impacted Areas

- Higher soil bulk density & lower porosity in impacted areas implies a rearrangement of finer soil particles, resulting in a loss of larger pore-size fractions ?
- This implies also that we should expect a lower saturated hydraulic conductivity?
- Greater runoff potential?

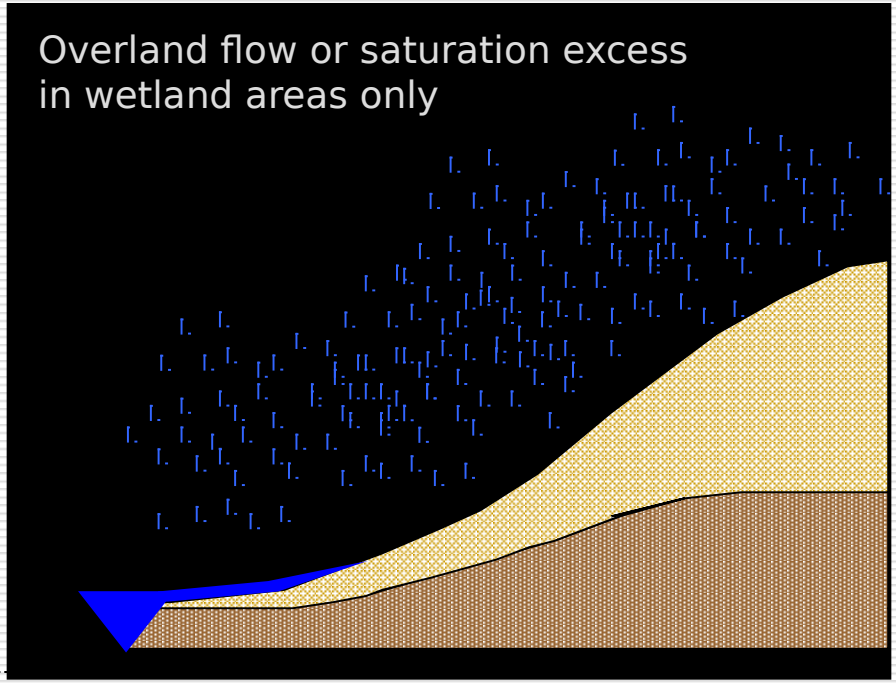
Watershed Flow Processes



- For L_1, it would With K_{sat} = 30 cm/hr, it would take 150 days to arrive at the stream
- And for L_2, it would take 250 days to arrive at the stream
- Water from the uplands do not contribute to short-term hydrograph

Watershed Flow Processes

- Upland areas in non-training areas do not contribute to the stream hydrograph, except in subsurface recharge
- Hydrograph response to rainfall events in non-training areas shows that wetlands are responsible for stream-flow contribution



- In training areas, roads “short-circuit” the watershed and allow runoff to contribute to the stream hydrograph

Hydrologic Indicators

- Soil-water storage may be an appropriate indicator of ecological change
  - Soil Water Retention Curve (SWRC) spatial data important for hydrologic modeling
  - Soil-water storage patterns important for hydrologic modeling and dynamics of vegetative processes
- K_{sat} may not be an appropriate indicator of ecological change, due to high heterogeneity in training areas.

Watershed Hydrology

- Watershed hydrology and nutrient dynamics

Identify and analyze physical characteristics of watersheds, land use patterns, and chemical variables associated with surface and subsurface hydrology that may be used as indicators of ecological change

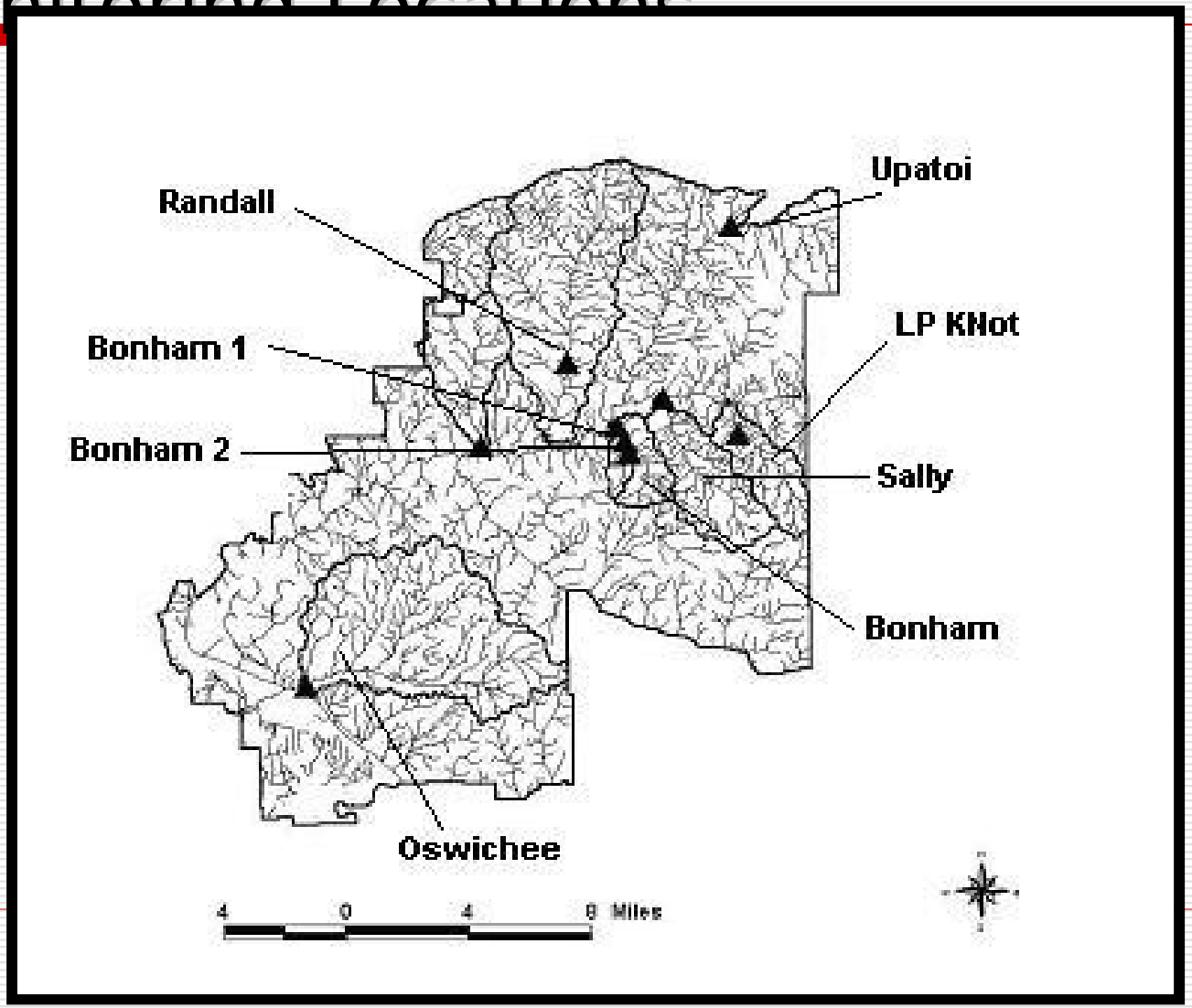
Watershed Physical Characteristics and Water Variables

Watershed Characteristics: Area, Average elevation, Average slope, Percentage of forest/wetlands, Percentage of military land use, Road density, Stream density

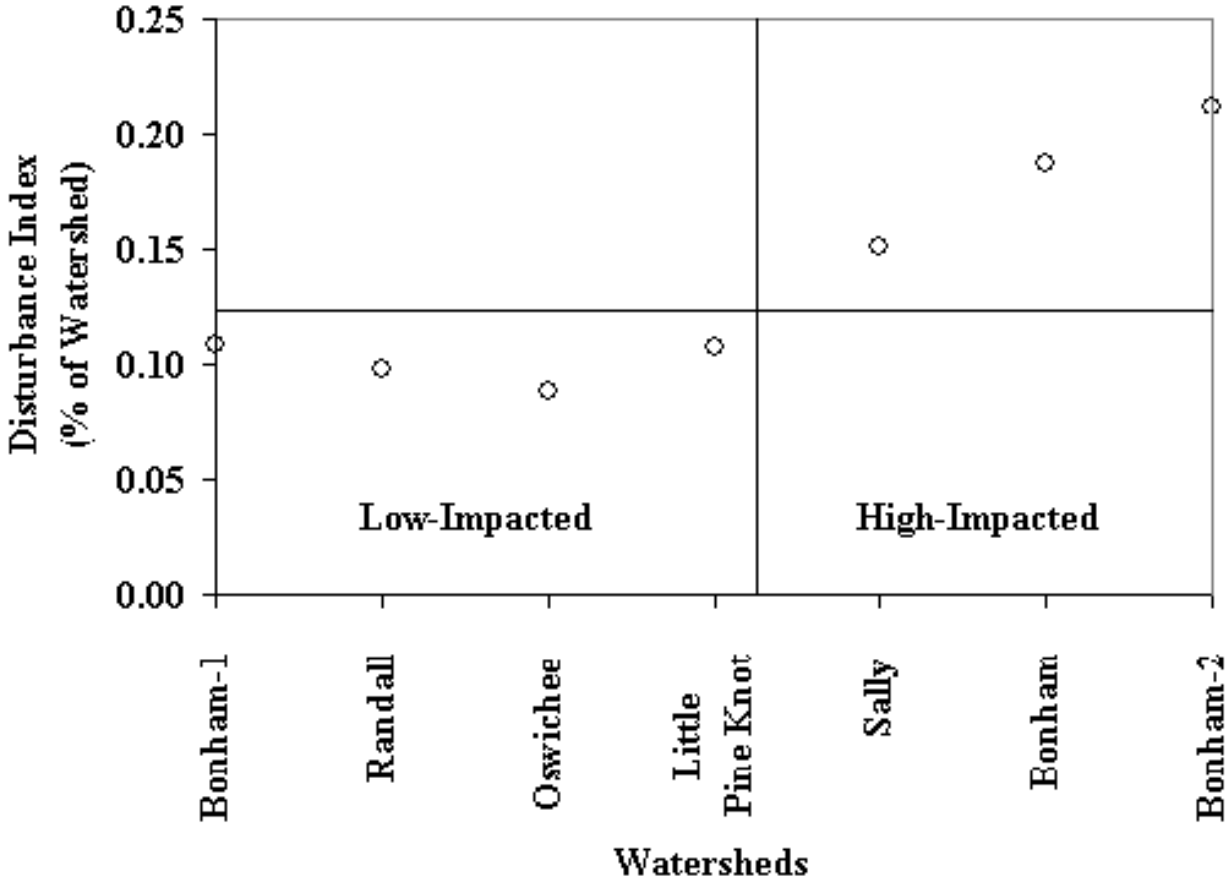
Water Quality Variables: pH, Temperature,Conductivity, Total Kjeldahl Nitrogen, Total Phosphorus, Total Organic Carbon, Chloride, Total Suspended Solids

Water Quantity Variables: IHA Statistics, Magnitude of monthly water conditions, Magnitude and duration of annual extreme water conditions, Timing of annual extreme water conditions,

Stream Hydrology and Chemistry Monitoring Locations

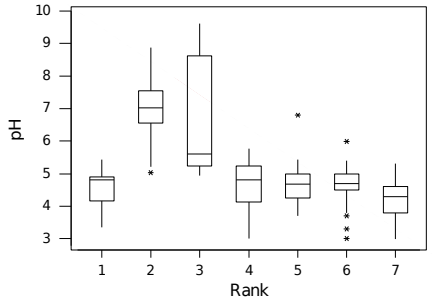


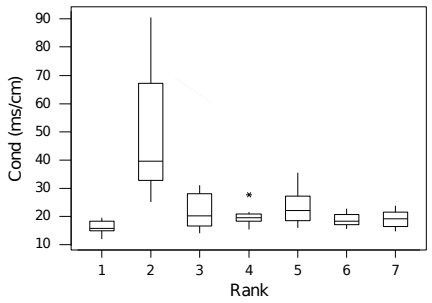
Disturbance Categories

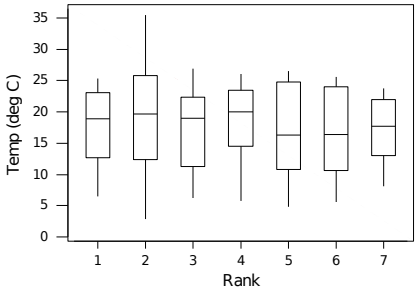


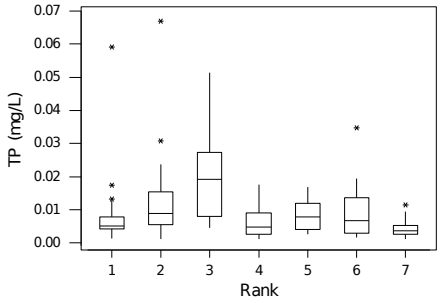
Categorization of watersheds is based on percent of bare land in each watershed. Low-impacted watershed consists of 11% or less bare land, high-impacted watersheds consists of 11% or higher bare land.

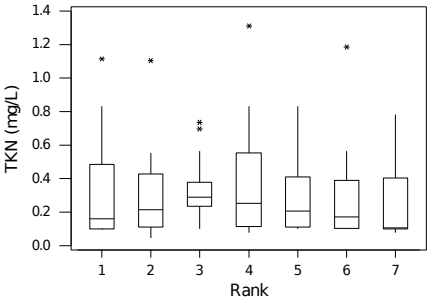
Stream Water Quality

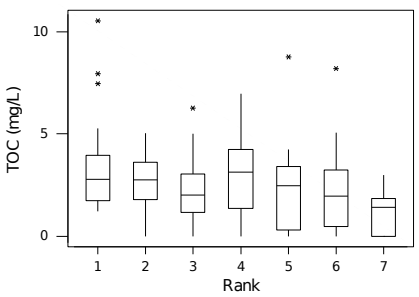


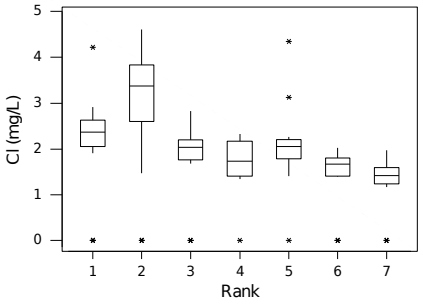


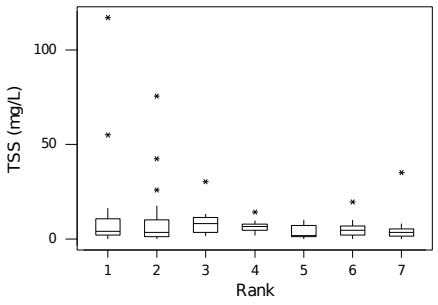












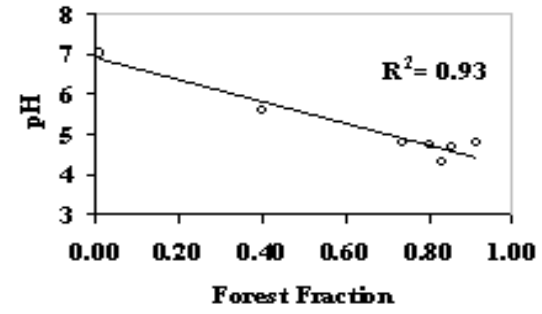
Rank	Streams
1	Bonham 1
2	Randall
3	Oswichee
4	LP Knot
5	Sally
6	Bonham
7	Bonham 2

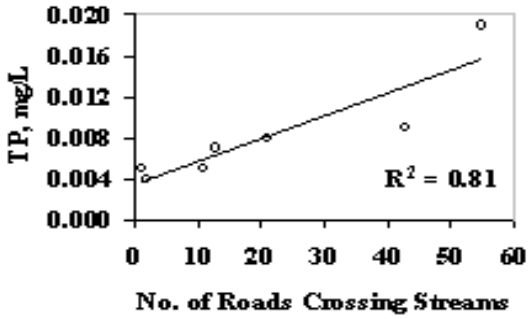
Water Quality Summary

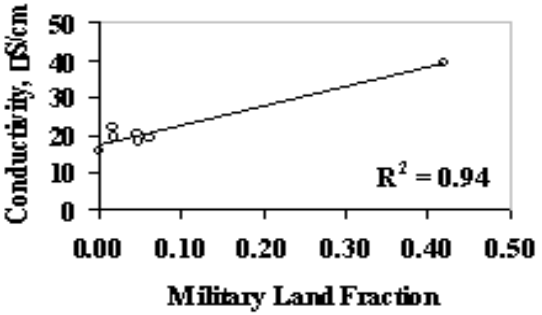
Parameter	Variability (Noise)	Sensitivity
pH	Moderate	High
Temperature	High	Low
Conductivity	Low	High
TP	Low	Moderate
TKN	High	Low
TOC	Moderate/High	Moderate
Cl	Moderate	High
TSS	Low	Moderate

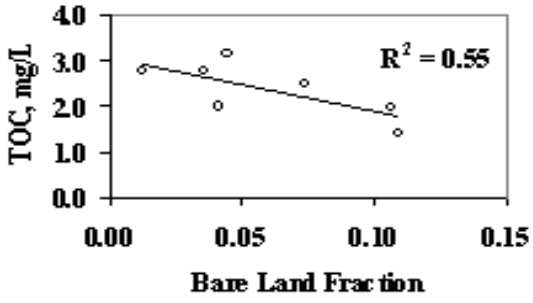
Scale of Indicator Potential: Excellent, Good, Fair, Poor

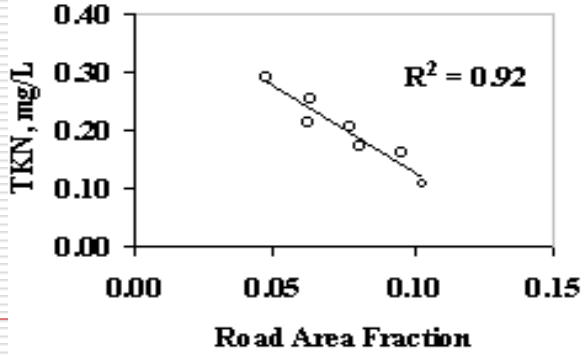
Water Quality Parameters and Watershed Characteristics

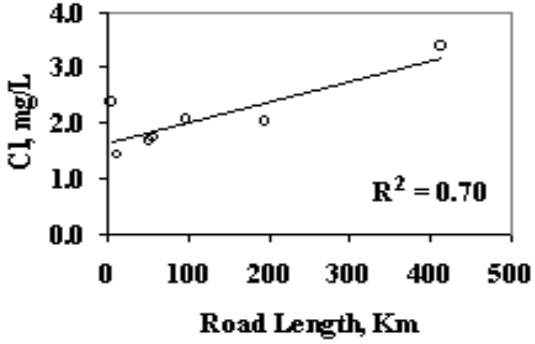












Water Quality Parameters and Watershed Characteristics

Water Quality Parameters	Independent Variables Retained and Regression Equations	R^2
pH	Forest, Stream Density, Bare Land 5.31 – 3.06 FOR + 0.663 STD + 3.29 PBL	0.99
Temperature	Total Bare Land 21.5 – 23.5 TBL	0.55
Conductivity	Military Land 17.4 + 52.4 MIL	0.94
TP	Road Length, No. of Roads Crossing Streams 0.0035 + 0.000025 RDL + 0.000364 NRS	0.98
TKN	Total Bare Land 0.337 – 1.00 TBL	0.61
TOC	Bare Land 3.08 – 11.8 PBL	0.54
Cl	Road Length 1.66 + 0.00368 RDL	0.70
TSS	–	–

All Variables Retained at the Model are Significant at the 0.05 level

Conclusions:

- Biogeochemistry
  - Soil Carbon, A-horizon
  - Microbial biomass, enzymes, and microbial activities
  - Hyperspectral analysis of Level 1 indicators
- Vegetation
  - Species associated with severe disturbance
  - Separation of 0-3, 8-10, and 30-80 yrs. post disturbance
- Watershed hydrology
  - Soil water storage
  - Riparian areas main contributor to stream baseflow and water quality

Conclusions:

- Aquatic Indicators
  - Stream water quality
  - Watershed characteristics
  -

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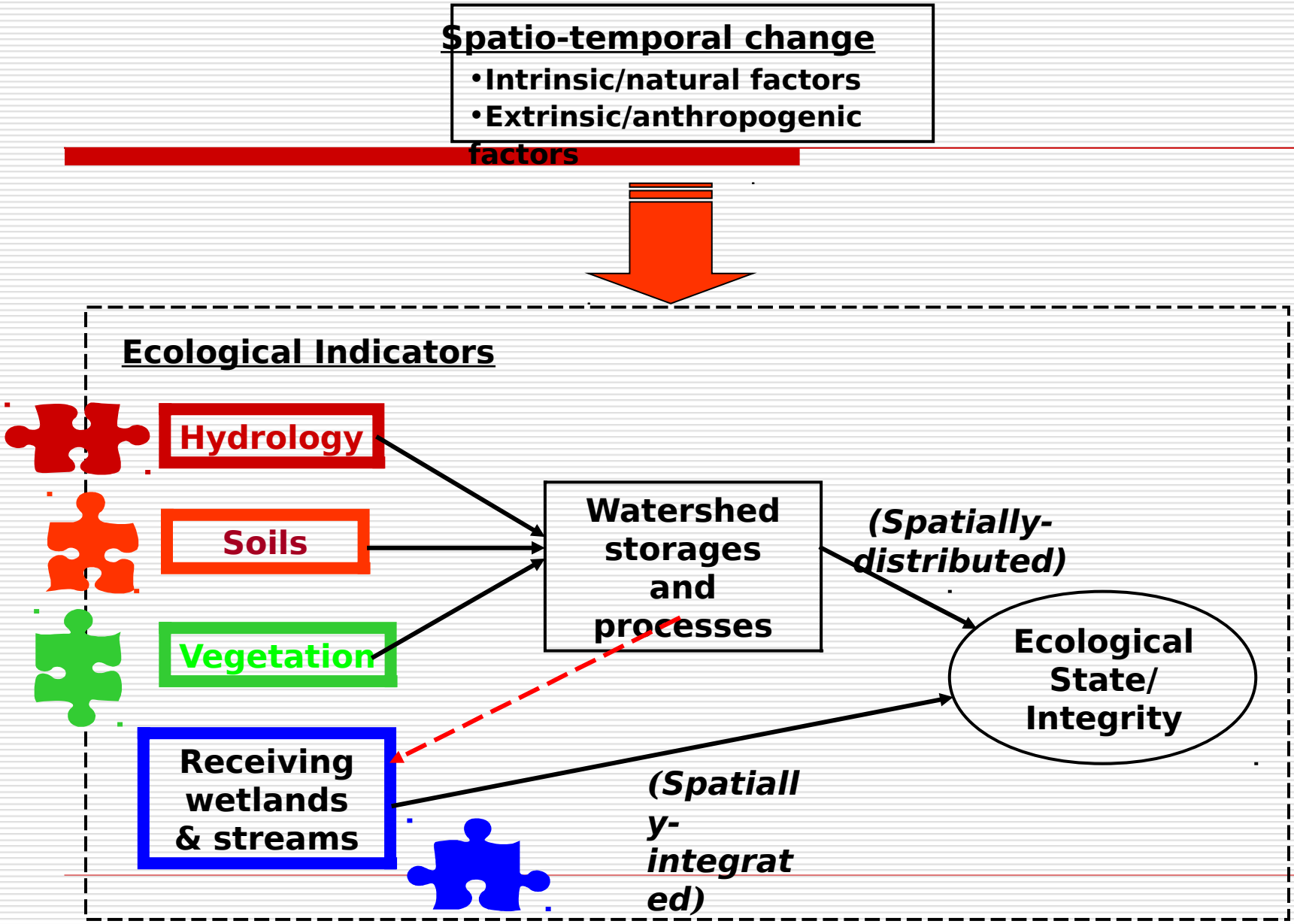
Research in Progress FY 2003-04


Spatio-temporal change
•Intrinsic/natural factors
•Extrinsic/anthropogenic factors
Ecological Indicators
Hydrology
Soils
Vegetation
Receiving wetlands & streams
Watershed storages and processes
(Spatially-distributed)
Ecological State/ Integrity
(Spatially-integrated)

Final Phase

- Fieldwork Completed
  - Parameterization of Riparian Ecosystem Management Model
  - Validation (resample of Bonham)
  - Diffuse Reflectance Spectroscopy (DRS)
- Ongoing
  - Litter Decomposition: Soil Carbon
  - Soil Aggregation

Future Work

- Ongoing
  - Phase I vegetation data sorted by time since clear cut
  - CCA and Indicator analysis Phase I data after realigned by silviculture
  - Access response of Avifauna to silvicuture modification of understory vegetation to determine potential use of individual bird species as indicators of habitat change

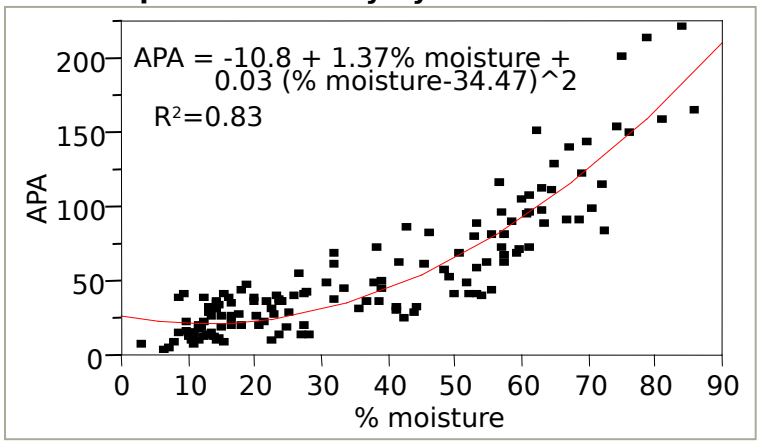
Litter Decomposition: Carbon Dynamics

Objective

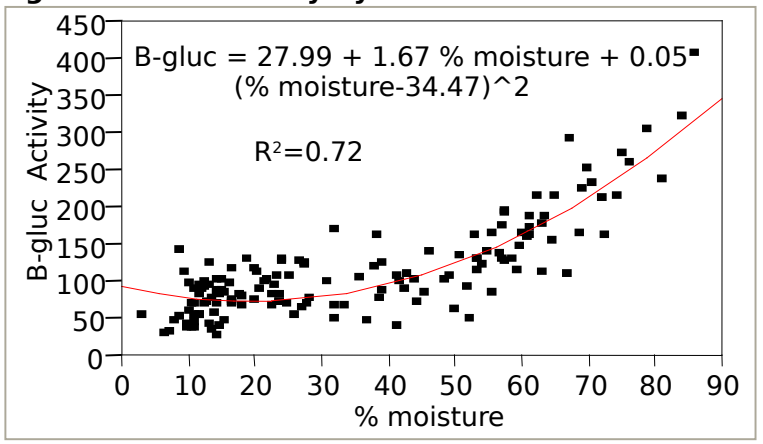
- Temporal responses in plant litter decomposition as influenced by land use.
  - Litter turnover rates
  - Microbial communities
  - Nutrient availability
  - Low, Moderate, High Impact
  - Bottomland and Upland

Enzymes and Soil Water Storage

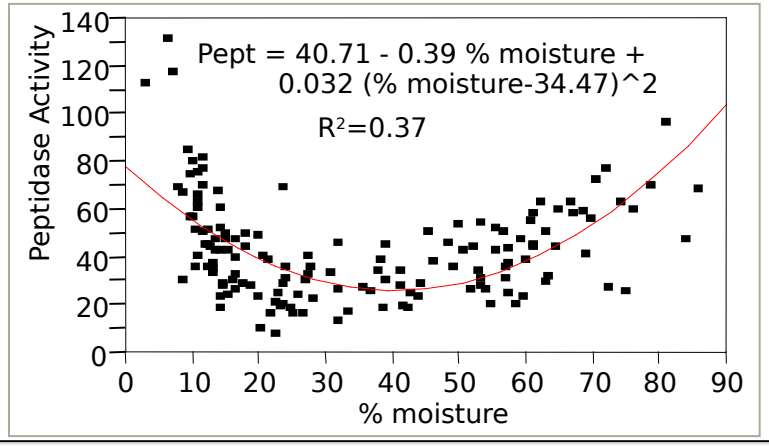
Acid Phosphatase Activity By % moisture



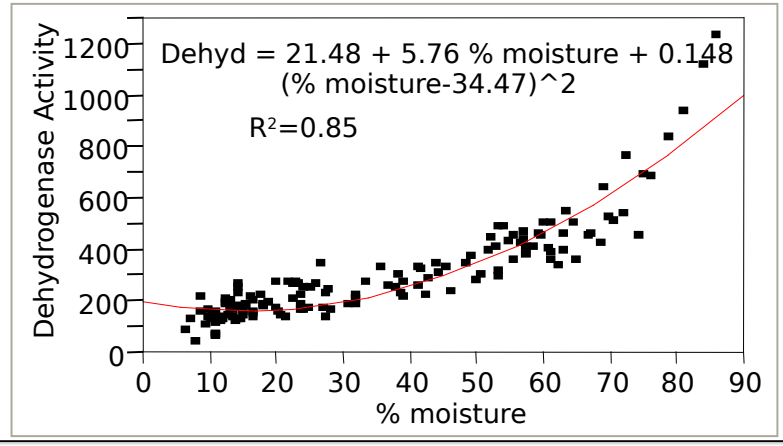
B-glucosidase Activity By % moisture



Peptidase Activity By % moisture



Dehydrogenase Activity By % moisture



Soil Organic Matter Size and Density

Objectives

- Define the soil organic matter size and density fractions
- Determine the nutrient pools in the soil organic matter
  - Low, Moderate, High Impact
  - Bottomland and Upland

Hyperspectral Scanning of Soils

- Determine whether spectral signatures can be used to discriminate ecological impact.
- Determine the relationship between biogeochemical properties of soils and spectral reflectance
- Conduct *in situ* analyses to determine if relationships hold in the field

Correlation of soil biogeochemistry with watershed hydrology model

Determine soil chemical and biogeochemical parameters that affect stream and ground water chemistry

Riparian Wetlands

- Riparian wetlands are integrators of watershed impacts
- Determine key biogeochemical indicators in riparian wetlands
- Relate biogeochemical indicators to watershed characteristics
- Relate biogeochemical indicators to stream water quality

Research Products

- Graduate students
  - 6 M.S students
  - 3 Ph. D students
- Presentations at professional meetings
- Refereed publications
- Outreach publications